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Environmental Monitoring Report
for Calendar Year 1983

May 1, 1984

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1. Introduction

This report gives the results of the environmental monitoring program at Fermi National Accelerator Laboratory (Fermilab) for Calendar Year (CY-) 1983. The Fermilab Facility is a proton synchrotron with an original design energy of 200 GeV (billion electron volts). As a result of accelerator improvements, protons were accelerated to an energy of 500 GeV in 1976 and operation at 400 GeV was routine between 1976 and 1982 using conventional magnets. The primary purpose of the installation is fundamental research in high energy physics. In addition, cancer patients are being treated using neutrons released by the interaction of 66 MeV protons from the second stage of the accelerator. A major program has just been completed to construct, install, and operate a ring of superconducting magnets. The goal is to produce higher energy protons using less electrical power. Protons were accelerated to 700 GeV using superconducting magnets in 1983. Collisions of protons and antiprotons each having 1 TeV (1000 GeV) are planned.

The proton beam extracted for high energy physics from the 2 km (1.2 mi) diameter main accelerator is taken to three different experimental areas on site (Meson, Neutrino and Proton Labs in the Research Area in Fig. 1). All three of these areas received proton beams for the first time in 1972. Radioactivity is produced as a result of the interaction of the accelerated protons with matter. Operation of the accelerator produces some radiation which penetrates

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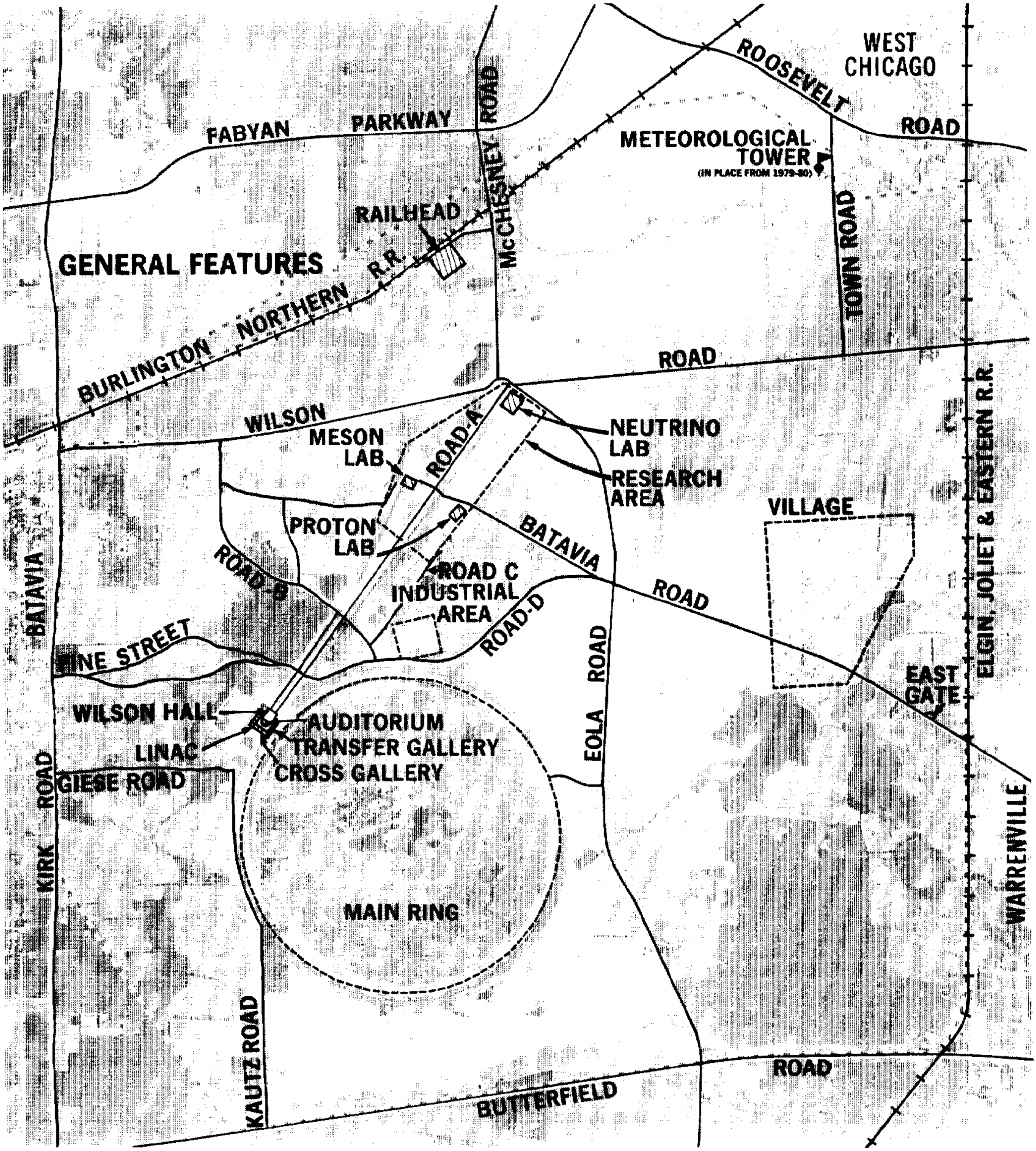
FIGURE 1



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the shielding material as well as some airborne radioactivity. Also, some radioactivation occurs in the soil and in the water used to cool beam components. A thorough evaluation has been made of the on-site discharges as well as the potential for off-site releases of radioactive effluents. An extensive monitoring program is being carried out to verify that radiation exposures are far below the permissible limits.

The Fermilab environmental radiological monitoring program follows, in general, the guidance given in the Department of Energy (DOE) report _A Guide for Environmental Radiological Surveillance at DOE Installations._[1] This includes adherence to the standards given in DOE orders, in particular, DOE Order 5480.1A, Chapter XI, which pertains to permissible doses and concentration guides, and gives guidance on maintaining exposures to as low as reasonably achievable (ALARA).[2] In addition, the environmental monitoring is supplemented by effluent monitoring following, in general, the guidance given in the Department of Energy (DOE) report _A Guide for Effluent Radiological Measurements at DOE Installations._[3]

The emphasis has been placed on exposure pathways appropriate to high energy physics laboratories. These pathways include external exposure from direct penetrating radiation and airborne short-lived ^{11}C, and internal exposure from ^{3}H and ^{22}Na in water, primarily drinking water. There is one unique characteristic at Fermilab which requires consideration and that is the use of large volumes of sand and gravel in two locations to assist in stopping the high energy protons and secondary particles. Although the ground water beneath these two areas is protected by membranes impervious to water and by underdrain systems to collect the water, monitoring is necessary.

Monitoring results are also reported for nonradioactive pollutants. Included as pollutants are pesticides used in weed, insect, rodent, and algae control. In addition, results are included from monitoring the performance of the sewage treatment plant on site. Discharges of suspended solids from this plant have sometimes exceeded permit limits.

Fermilab is located in the greater Chicago area (Fig. 2) on a 27.5 km^2 (10.6 mi^2) tract of land in an area which is rapidly changing from farming to residential use. There are many municipalities in the vicinity, resulting in a distinct pattern of high population concentration. Within a 3 km (2 mi) distance from the Laboratory boundaries, Batavia (pop. 12,574), Warrenville (pop. 7,519), and West Chicago (pop. 12,550) can be found (Fig. 3).[4]

The two major environmental features near the Laboratory are the Fox River to the west, which flows south through Batavia with an average of 1900 million liters (500 million gallons) per day, and the west branch of the DuPage River which passes east of the site flowing south with an average of 265 million liters (70 million gallons) per day through Warrenville. The rainfall on site during 1983 was 97 cm (38 in).[5] The land on the site is relatively flat with a high area, elevation 244 m (800 ft) above mean sea level (MSL), near the western boundary and low point, elevation 218 m (715 ft), above MSL, toward the southeast. The drainage of

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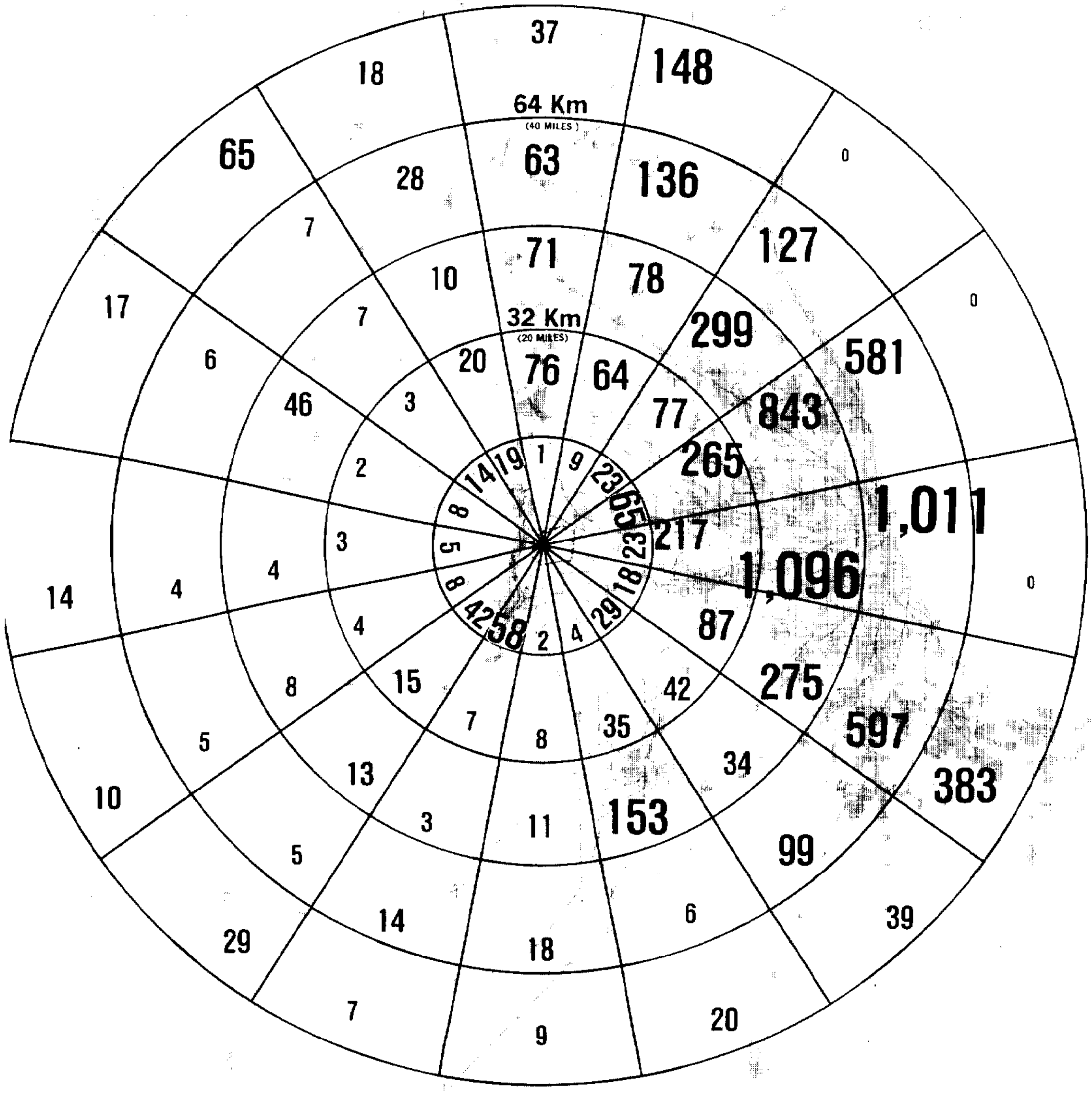
FIGURE 2



NOTE: NUMBERS REPRESENT NEAREST 1000.

POPULATION DISTRIBUTION -1980
(1980 CENSUS)

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REGIONAL AREA SURROUNDING FERMI NATIONAL ACCELERATOR LABORATORY

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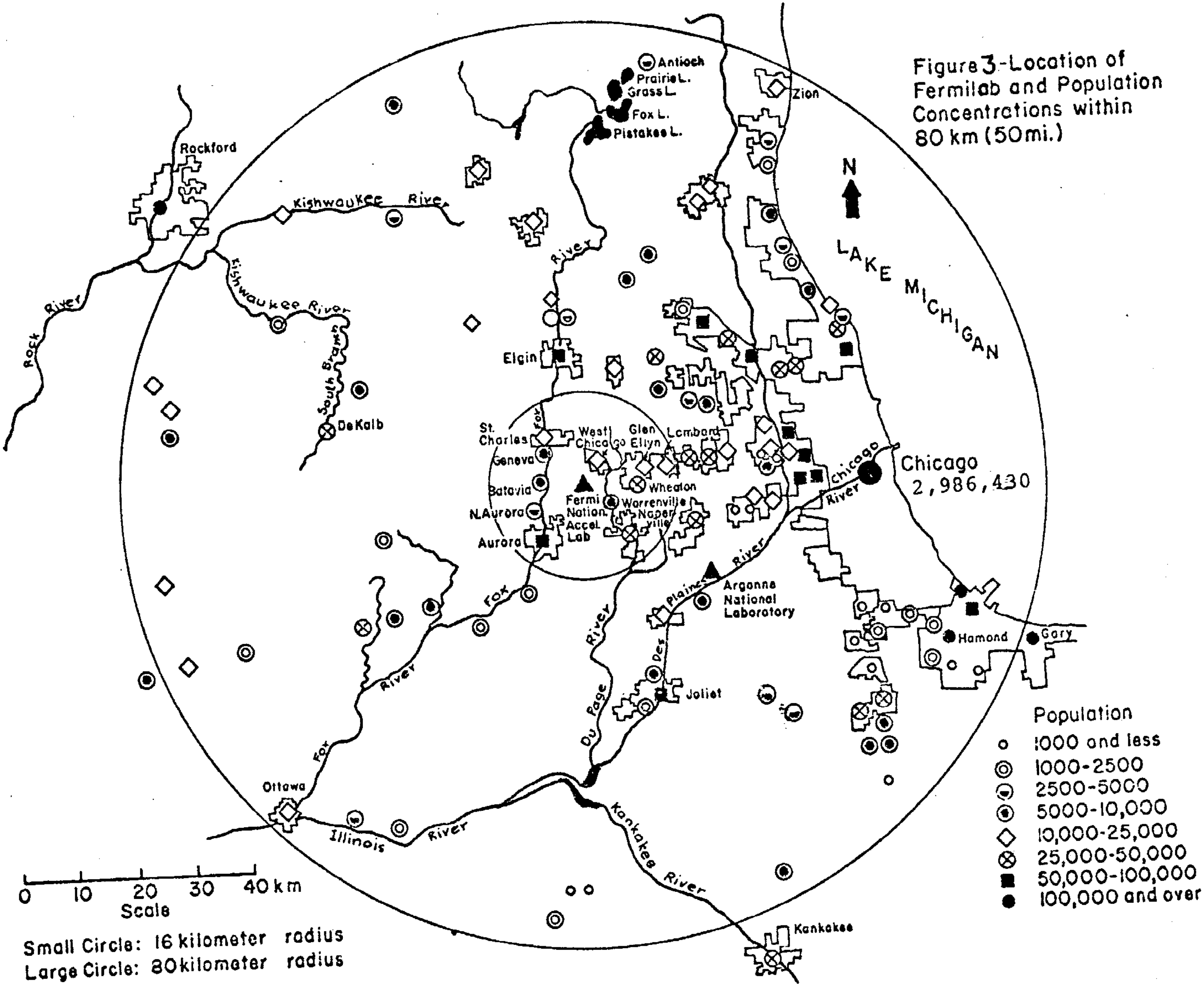

Figure 3-Location of Fermilab and Population Concentrations within 80 km (50mi.)

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the ground water and most of the surface water is toward the southeastern corner of the Laboratory, toward the DuPage River. A somewhat smaller amount drains to the southwest, toward the Fox River. The drinking water in many of the surrounding communities comes from deep wells usually drilled 360 m (1200 ft) deep into the Cambrian/Ordovician aquifer system.[6]

In CY-1983 the meteorological data was obtained from the National Weather Service Office at O'Hare International Airport, Chicago, Illinois. In CY-1983 the average wind speed at O'Hare Airport was 4.7 m/sec (10.4 mi/hr). Fermilab is about 43 km (27 mi) from the airport and the terrain between them is relatively flat.

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2. Summary

The accelerator began an extended shutdown for installation of a superconducting magnet ring in June 1982. Injection of protons into the new accelerator ring began one year later. Extraction of protons to the Experimental Areas occurred in October 1983. The total number of protons accelerated in 1983 was 4×10^{17}. This total is approximately 2% of the average of 1.9×10^{19} for the preceding five years. Thus, environmental monitoring in CY-1983 was done mainly to check on effects resulting from previous accelerator operations.

During CY-1983 there were no abnormal occurrences which had an impact on the facility and its operation. This year 8.3 km^2 (2045 acres) was sprayed with 2, 4 D for controlling noxious weeds. In the past as much as 10 km^2 (2500 acres) was sprayed with 2, 4 D.

The maximum potential radiation exposure at the site boundary during CY-1983 (fence line assuming 24 hr/day occupancy) was only 0.04 mrem compared to 0.5 mrem last year. This dose would correspond to 0.008 percent of the standard of 500 mrem for an individual who is not a radiation worker (Section 5). The maximum individual potential exposure would be essentially the same because the decrease in dose rate is small between the site boundary and the location of that individual.

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The total potential radiation exposure to the general off-site population from Fermilab operations during CY-1983 was less than 0.1 person-rem compared to 3 person-rem last year. The primary source of potential exposure was penetrating radiation from muons this year. All exposure was from external radiation, as was the case in the past. Thus, the 50 year dose commitment from operations in 1983 is expected to be the same as the exposure received in 1983.

No airborne radioactivity was released across the site boundary in CY-1983 during accelerator operations because the Neutrino Area primary beam line was not receiving protons. In the past airborne radioactivity was released from the stack ventilating a Neutrino Area enclosure where the proton beam strikes a target. There was a controlled release of tritium in tritiated water evaporated as a means of disposal. The total quantity released to the atmosphere in CY-1983 was 42 mCi, about 72% of last year´s release. The concentration at the site boundary was less than 0.01 percent of the Concentration Guide (Sections 3.2 and 5), resulting in a negligible off-site exposure. The off-site release of tritium in surface water totaled approximately 658 mCi, about 25% greater than last year´s release. The primary source of tritium is one sump discharging in the Neutrino Area from an underdrain system beneath the target which has received most of the protons.

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3. Monitoring, Data Collection, Analyses, and Evaluation

The three types of accelerator-produced radiation which receive extensive environmental monitoring are discussed below. These radiations have direct pathways to the off-site population. Other more indirect pathways, such as through the food chain, have received much less attention to date. The decision on what to monitor is based on the type of operation, radionuclides released, potential hazard, and monitoring results from this and other high energy physics laboratories.

3.1 Penetrating Radiation

Operation of the accelerator at current energies and intensities results in production of some penetrating radiation (primarily muons) outside the shielding. The shielding has been designed to be adequate for much higher intensities; therefore routine monitoring was done for purposes of determining actual radiation levels only on the site this year. Off-site doses were based on the on-site results and off-site measurements made in previous years.

A large network of detectors was used to monitor penetrating radiation. At the end of CY-1983 there were approximately 120 detectors deployed around the site for the main purpose of protecting on-site personnel. The majority of these detectors were connected to a data logger which automatically recorded the radiation levels for subsequent examination.[7] Because the intensity was so low in CY-1983 only three

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detectors were used primarily for environmental radiation monitoring. One was a large volume, 110 liter, ionization chamber (called a Hippo) for gamma-ray and charged particle detection. It was located near the Boneyard at the Railhead (Fig. 4). One of the remaining two detectors was a large scintillation counter. The other was a tissue-equivalent ion chamber. The large scintillation counter is located near the site boundary (Environmental Monitoring Station in Fig. 4). The ion chamber is located at 14 Shabbona in the Village (Fig. 4).

The Mobile Environmental Radiation Laboratory (MERL) was used in the past for determining the exposure levels at the site boundary and for locating the sources of penetrating radiation such as muons and neutrons.[8,9,10,11] The MERL is a four-wheel-drive vehicle equipped with two 20 cm x 20 cm (8 in x 8 in) scintillation counters, one approximately 15 cm (6 in) behind the other, for muon detection. It also has a dePangher "long counter" for neutron detection.[12] Since the radiation levels were so low this year, this opportunity was taken to refurbish the MERL. Reliance on fixed detectors was made to determine that no unexpected exposures occurred.

3.1.1 Muons

Measurements of muons from the Proton Area (Proton West and Proton East in Fig. 5) which were made in CY-1980 with 350 GeV protons were repeated in CY-1981 with 400 GeV protons.[10] Measurements were made both on and off the site. Also, radiation surveys were made using hand-held survey

Figure 4. - Fermilab Site

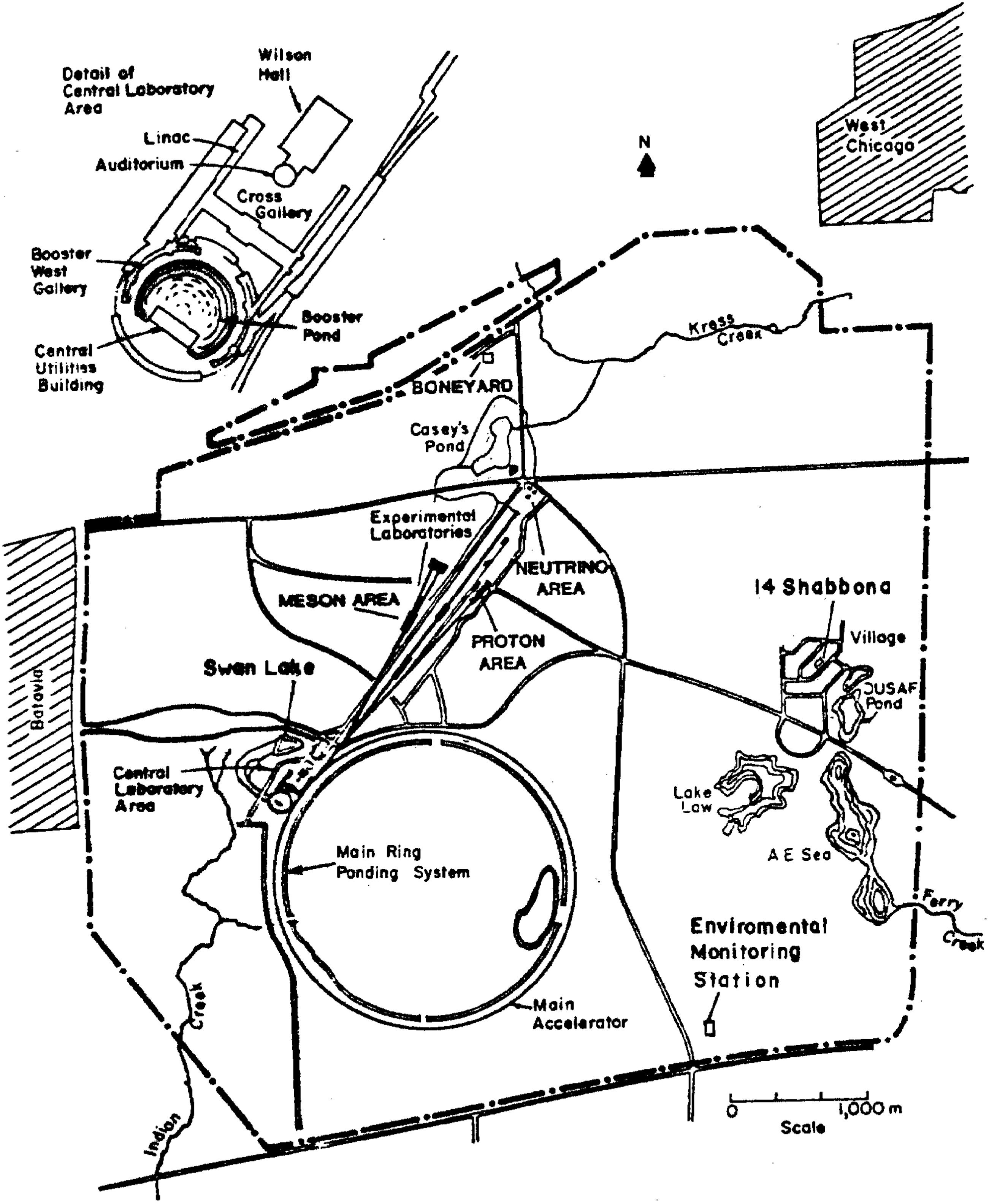

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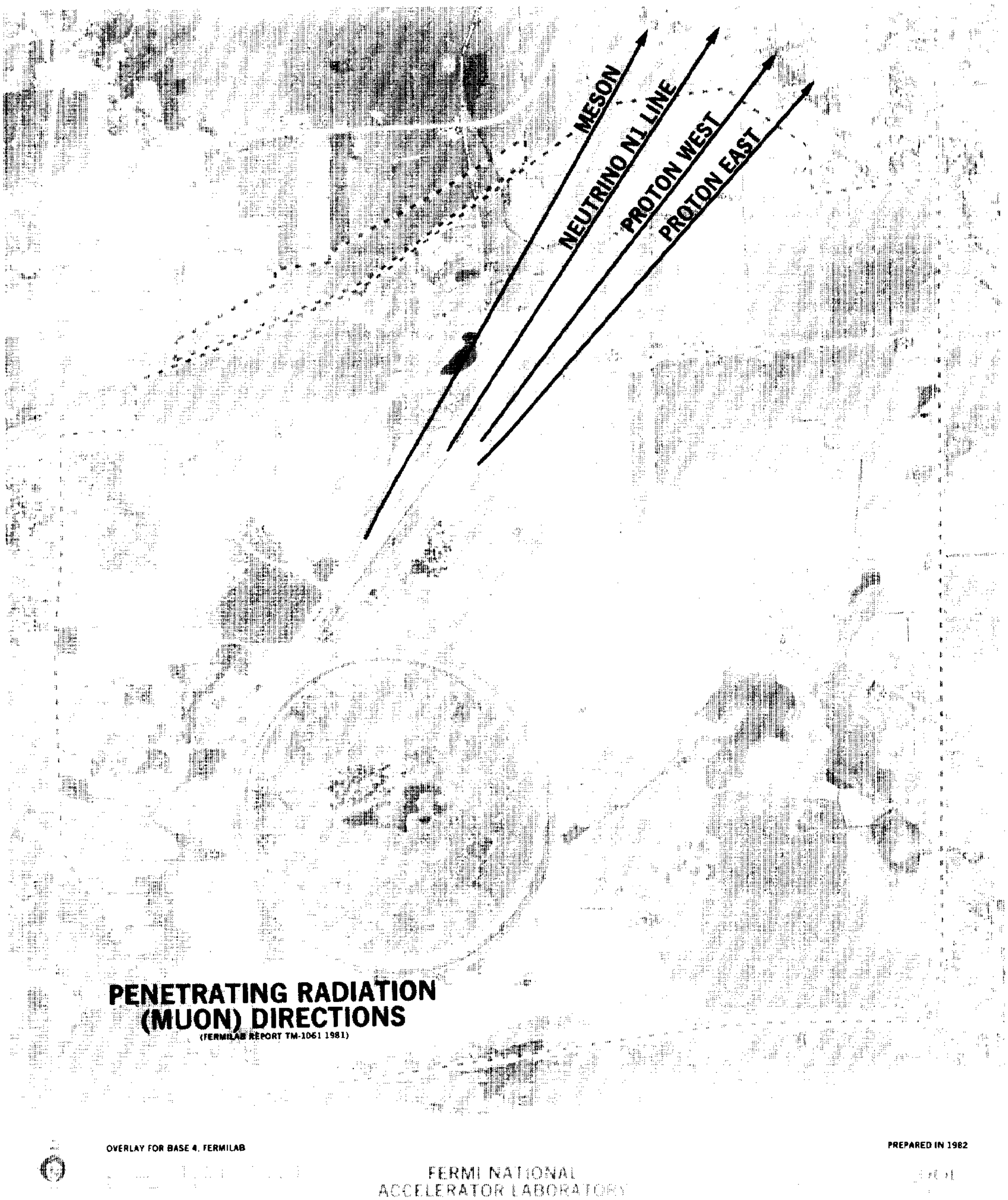
FIGURE 5



PENETRATING RADIATION (MUON) DIRECTIONS

(FERMILAB REPORT TM-1061 1981)

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instruments close to the source. In CY-1982 the radiation surveys close to the source were repeated and agreed with the CY-1981 measurements. The site boundary muon dose rate for CY-1983 was then determined from the CY-1981 measurements and the number of protons incident on the targets. The fence line annual dose based on 24 hour per day occupancy was 0.04 mrem for CY-1983 for the Proton Area. Since the dose rate varied inversely with distance and the distance to the nearest off-site individual was small compared to the distance from the muon source, the maximum individual dose rate was approximately the same as the fence line dose in CY-1983.

Based on the CY-1981 measurements and the number of protons sent to the Experimental Areas in CY-1983, the fence line doses for CY-1983 were negligible for the Meson Area and for the Neutrino Area.

3.1.2 Neutrons

Neutrons penetrated the shielding in the most easterly of the external experimental areas (Proton East line in Fig. 5) in the Proton Area in CY-1982.[8,11] However, in CY-1983 additional shielding was added to this area and a different experiment was performed. The result was that a negligible number of neutrons penetrated the shielding.

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3.1.3 Gamma Rays

The primary radioactive waste storage area on site - the Boneyard - is also the primary source of off-site gamma radiation. As shown in Fig. 4, this area lies close to the site boundary. On the north side there is an earth berm to prevent any direct radiation from leaving the site. Shielding has been provided above and on all sides of those radioactive materials which would produce high radiation levels without shielding. This was done to protect Fermilab workers as well as reduce the off-site dose. The items responsible for most of the site boundary dose rate in the past[13] were disposed of in an approved off-site burial ground in late CY-1979. Most of the remaining inventory was shipped in CY-1982. Radiation levels at the site boundary closest to the Boneyard were at background levels in CY-1983.

3.2 Airborne Radioactivity

Radioactivation of air in measurable concentrations will occur wherever the proton beam or the spray of secondary particles resulting from its interactions with matter passes through the air. Along most proton beam lines (paths of the protons from the accelerator) the protons travel inside evacuated pipes. Thus, radioactivation of air is now usually caused by secondary particles. Monitoring of such activation is carried out for purposes of personnel exposure control. Under no circumstances is the off-site concentration of airborne radioactivity expected to approach the limits for uncontrolled areas. During CY-1983 the primary target in the

Neutrino Area was not in operation. This target has been the source of radioactive gas, primarily ^{11}C, which was produced by interaction of secondary particles from this target with air.

A debonding oven was placed in operation in CY-1979 in the Industrial Area (Fig. 1). Its purpose is to debond magnets by decomposing the epoxy adhesives at high temperatures. Most of these magnets are radioactive, having failed during accelerator operations. The gaseous effluent was measured during the acceptance test on June 8, 1979 conducted for the Illinois EPA and contained only ^{3}H at very low levels. No radioactive magnets were debonded in CY-1983, hence, no ^{3}H was released this year.

A water evaporator was placed in operation in CY-1981 at the Boneyard (Fig. 4) to dispose of tritiated water collected from closed loop cooling systems. A new evaporator was placed in operation in CY-1983 and a total of 7200 ℓ (1900 gal) of water containing a total of 42 mCi of ^{3}H was evaporated. The average concentration at the site boundary was less than 0.01 percent of the Concentration Guide[3] (Section 5) using the Gaussian plume diffusion model[14] with neutral wind conditions.[15] Soil and vegetation samples were taken in the vicinity of the old and new evaporators. See Sections 3.3.2.3 and 3.3.3.

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3.3 Waterborne Radioactivity

During accelerator operations, some radioactivation of the soil will occur.[16,17] Leaching of these radionuclides into the ground water provides a possible mechanism for transport of Fermilab-produced radionuclides into the surface run-off waters and aquifer. Hence, a broad program of ground water monitoring for radioactivity is maintained. Measurements are also made of on-site concentrations of radionuclides in Fermilab surface waters and in closed loop (recirculating) cooling systems which are sources of potential off-site releases.

Water samples are collected periodically on site and from surface waters off site. They are analyzed for the presence of those radionuclides which are produced in and leachable from Fermilab soils in measurable quantities.[16] This group of radionuclides also includes those produced in water directly. Analyses are made for ^{3}H, ^{7}Be, ^{22}Na, ^{45}Ca, ^{54}Mn and ^{60}Co. The latter is hardly leachable (approximately 0.1 percent); however, it has been detected in discharges during regeneration of water treatment resin.

Water samples were collected from the following types of wells on site:

1. Farm Wells - Approximately 30 m Deep - 30 Samples

2. Fermilab Water Supplies - Approximately 70 m Deep - 3 Samples

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3. Fermilab Deep Well Emergency Supply - 436 m Deep - 1 Sample

The wells routinely sampled are shown in Figure 6. Water samples were also collected from sumps, creeks, and rivers. All surface and ground water samples collected were analyzed by Teledyne Isotopes, Inc. (formerly Hazelton Environmental Sciences), 1500 Frontage Road, Northbrook, Illinois 60062. Each monthly shipment included at least one sample containing accelerator-produced radionuclides in known amounts to check the accuracy of the assays. See Section 4.

3.3.1 Water Sample Collection

To obtain water samples from wells not in regular use, the wells are pumped for a sufficient length of time to insure that the water standing in the pipe has been pumped out before a sample is taken. The water in the pipe could conceivably have been there since the last time a sample was taken. Normally, the pipe volume is pumped several times before sampling. Water samples from sumps, creeks and other surface waters are normally collected by dipping a bottle well below the surface. Several of the sumps inside normally locked enclosures are sampled by remotely operated peristaltic pumps or the sump pumps themselves.

The water sampling schedule is based on the following rationale:

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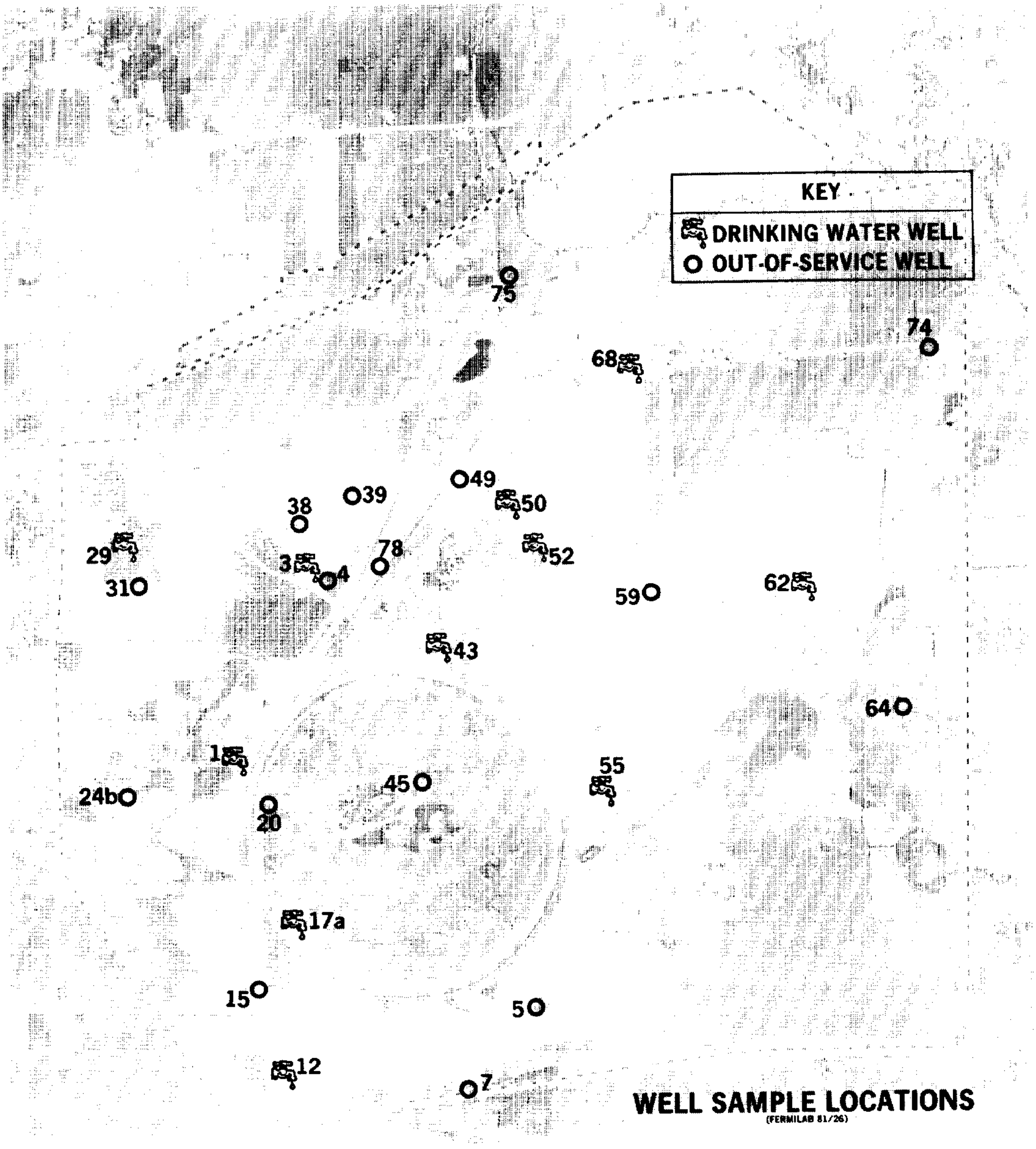
FIGURE 6



WELL SAMPLE LOCATIONS
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1. Wells 38/39*, 43, 49, & 78 are sampled quarterly because they are closest to the areas of maximum soil activation (near targets and dumps) and are in the direction the water would flow in the aquifer.

2. Wells 1, 5, 17A, 20, and 45 are sampled semiannually because they are near the accelerator.

3. The other wells are sampled annually because they are near the site boundary or serve as back-ups to the other wells or as drinking water supplies.

4. The one deep well is sampled annually to look for long-term trends or changes in percolation down to that level.

5. The MF5, N1, N2, and PW8 sumps are sampled bimonthly because they are the closest to the areas of maximum soil activation. See Figure 7.

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*38 and 39 are close to each other and sampled the same region of the aquifer. Each is sampled semiannually. See Figure 6.

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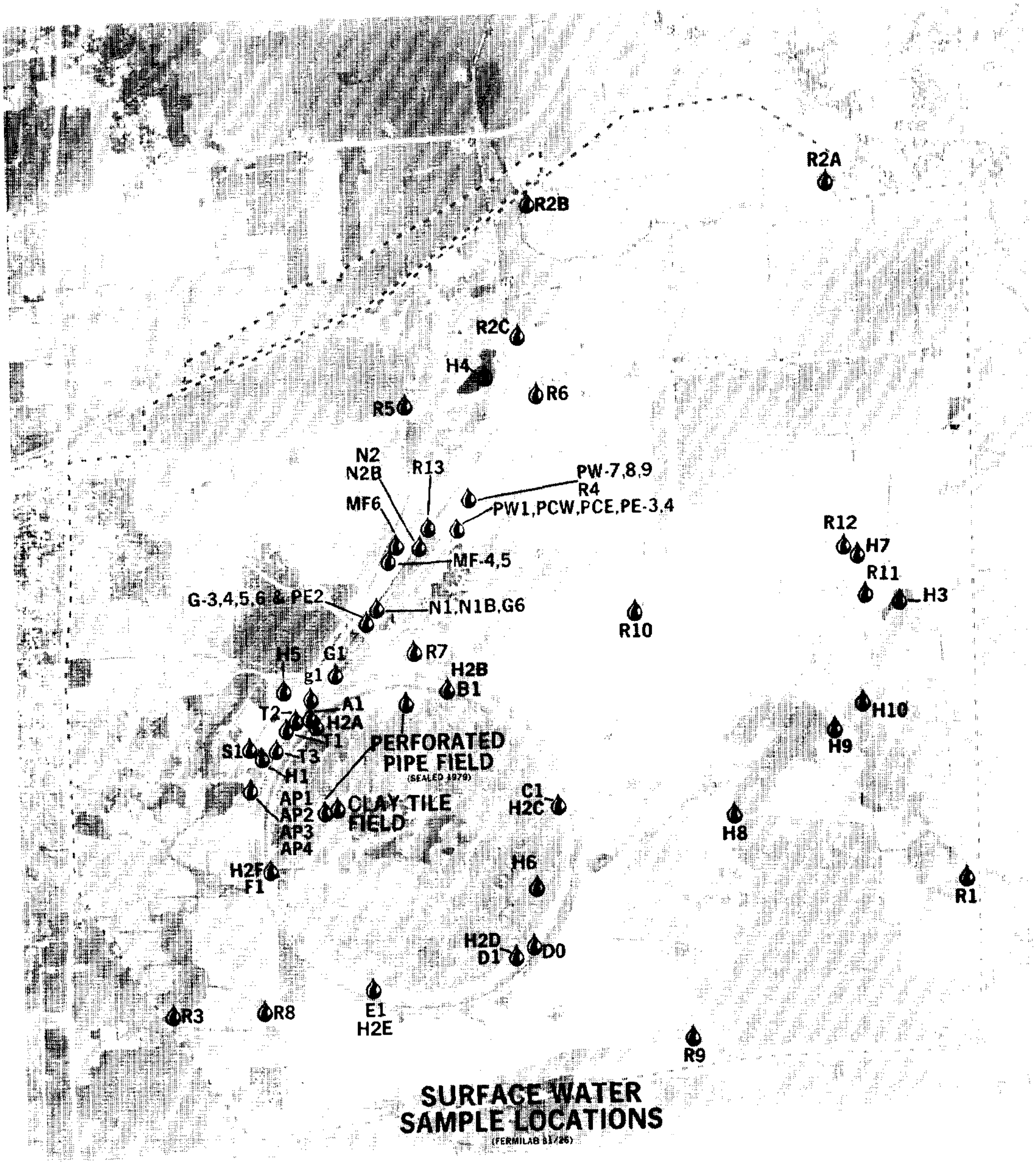
FIGURE 7



SURFACE WATER
SAMPLE LOCATIONS
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6. The MF4 sump and the N1 Retention Pit are sampled quarterly because the MF4 sump collects water from a region with less activity than that of the MF5 sump (outside the impervious membrane instead of inside) and the N1 Retention Pit does not have a pump in it even though it collects from a region of higher activity than the N1 sump.

7. The other sumps are sampled less frequently with the frequency based on the tritium concentration found there in the past.

8. The creeks are routinely sampled three times a year and Kress Creek is sampled monthly whenever water from the Laboratory flows over the spillway into the creek.

9. Ponds and ditches with a potential for receiving radioactive water are sampled annually.

10. The Fox River and west branch of the DuPage River which receive run-off from Fermilab are sampled annually.

11. The closed loop cooling systems which cool targets and dumps are sampled with a frequency which depends on the level of radioactivity. Operating systems having concentrations greater than 0.01 μCi/mℓ are sampled quarterly. Those having concentrations between 0.001 and 0.01 μCi/mℓ are sampled semiannually. Those between 0.00001 and 0.001 μCi/mℓ are sampled annually.

12. The resin regeneration systems are routinely sampled for analysis by an outside laboratory semiannually. Analyses are performed on site for samples from every regeneration sending radioactive effluent to the CUB tile field inside the Main Ring.

13. Several samples are collected annually to look for radioactivity leached from steel.

3.3.2 Results of Analyses

All current Fermilab water sampling locations for detection of accelerator-produced activity are shown in Figs. 6 and 7. Not all locations are sampled every year. See Section 3.3.1 above. No accelerator-produced radionuclides were reported in water samples taken from the three creeks leaving the site (R1, R2A, and R3 in Fig. 7). Samples were obtained as follows from each of the three creeks: Kress Creek four samples; Ferry Creek and Indian Creek, three samples each. River water samples were obtained once during CY-1983 from the Fox River in Aurora and from the west branch of the DuPage River in Warrenville (Fig. 3). Neither river is utilized as a drinking water supply. No evidence for accelerator-produced radionuclides was found.

The Village water supply (62 in Fig. 6) is the Laboratory´s only community water supply. Quarterly water samples were collected and a composite analyzed for naturally occurring as well as reactor and accelerator-produced radionuclides in CY-1980. No activity was found using

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very low detection limits. See Section 5. The same was true for composite samples from Fermilab's other two drinking water systems providing water to more than 25 persons a day. These (1, with 3 as back-up, and 55 in Fig. 6) supply water to Wilson Hall (Fig. 1) and to Site 55 and the east side of the main accelerator (Main Ring in Fig. 1). These drinking water systems received annual routine sampling in CY-1983. No accelerator-produced radionuclides were detected in the 34 samples taken from all on-site wells monitored in CY-1983.

3.3.2.1 Tritium

The results for on-site tritium measurements yielding detectable levels in surface waters (Fig. 7) are given in Table 1. All other sampling points were essentially at background levels. The sumps collect waters from around the footings of the buildings and enclosures. This water is considered surface water. Only aquifers are called ground waters. The total off-site release in surface waters was 658 mCi of tritium this year compared with 530 mCi last year. This increase was primarily because the concentrations in the N1 sump (Fig. 7) were higher during the first eight months of CY-1983 than they have been in the past. The release occurred at less than 0.3 percent of the Concentration Guide (Section 5) and made a negligible contribution to the potential off-site dose.

Detailed reports of off-site effluent releases and on-site discharges are made via the Department of Energy Effluent and On-Site Discharge Information Systems, EG&G, Idaho, Inc., P.O. Box 1625, Idaho Falls, Idaho 83401.

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TABLE 1

Tritium Detected in On-Site Water Samples

Tritium Concentration C ($\mu Ci/m\ell$)*

Collection Point	Number of Samples Collected	C Max	C Max Error	C Min	C Min Error	C Mean	Percentage of Relevant Standard
DO Sump	2	4.0×10^{-6}	4.0×10^{-7}	$< 1.3 \times 10^{-6}$	-----	2.7×10^{-6}	0.1
G4 Sump	3	8.8×10^{-6}	4.0×10^{-7}	2.9×10^{-6}	1.1×10^{-6}	5.8×10^{-6}	0.2
G5 Sump	4	1.0×10^{-5}	6.8×10^{-6}	2.8×10^{-6}	1.0×10^{-6}	5.3×10^{-6}	0.2
G7 Sump	2	3.0×10^{-5}	1.8×10^{-6}	6.8×10^{-6}	4.0×10^{-7}	1.8×10^{-5}	0.6
MF4 Sump	6	1.5×10^{-5}	1.6×10^{-6}	2.8×10^{-6}	1.7×10^{-6}	7.2×10^{-6}	0.2
MF5 Sump	6	1.2×10^{-4}	1.4×10^{-6}	5.0×10^{-5}	6.3×10^{-6}	8.4×10^{-5}	2.8
N1 Sump	5	3.1×10^{-4}	6.0×10^{-6}	3.6×10^{-6}	4.0×10^{-7}	1.7×10^{-4}	5.6
N2 Sump	4	9.1×10^{-5}	1.0×10^{-5}	3.7×10^{-5}	8.0×10^{-7}	7.5×10^{-5}	2.5
N2B Sump	2	9.8×10^{-6}	4.6×10^{-6}	$< 3 \times 10^{-6}$	-----	6.4×10^{-6}	0.2
PC East Sump	2	7.5×10^{-6}	1.3×10^{-6}	$< 3 \times 10^{-6}$	-----	5.2×10^{-6}	0.2
PC West Sump	2	5.4×10^{-6}	1.3×10^{-6}	$< 3 \times 10^{-6}$	-----	4.2×10^{-6}	0.1
PE3 Sump	3	3.3×10^{-6}	1.3×10^{-6}	2.6×10^{-6}	1.2×10^{-6}	3.0×10^{-6}	0.1
PE4 Sump	3	1.1×10^{-5}	1.3×10^{-6}	3.0×10^{-6}	3.0×10^{-7}	6.7×10^{-6}	0.2
PW8 Sump	5	1.7×10^{-5}	2.1×10^{-6}	4.2×10^{-6}	1.3×10^{-6}	8.2×10^{-6}	0.3
PW9 Sump	3	6.8×10^{-6}	4.0×10^{-7}	4.4×10^{-6}	1.2×10^{-6}	5.7×10^{-6}	0.2

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*C Max is the highest concentration detected in any sample from that location and C Min is the lowest. C Mean is the average for all samples from one location.

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The surface water from the experimental areas flows into Casey's Pond (Fig. 4) except during wet seasons. Then, the pond fills up and barricades are placed at the two entrances to the pond to keep the water from flooding the pump room. When these barriers, called stop logs, are in place, the water bypasses the pond and leaves the site via Kress Creek (Figs. 4 and 8). This was the case for one-third of the year in CY-1983.

No unplanned tritium releases occurred in CY-1983.

3.3.2.2 Beryllium

Concurrent with the production of ^{3}H with 12 year half-life is the production of ^{7}Be with 53 day half-life in the closed cooling water systems. The ^{7}Be is chemically active and is easily removed from the water by the resins used to maintain water purity. These resins are regenerated in two separate systems located at the Central Utilities Building (Fig. 4). The effluent from these two systems is sent to a clay tile field inside the main accelerator (Fig. 7). There it percolates into the soil about 60 cm (2 ft) below the surface. The short half-life of ^{7}Be and its strong chemical affinity with the soil ensure that the release will place no burden on the environment. The total amount of ^{7}Be discharged to the tile field in CY-1983 was less than one millicurie because the accelerator was shutdown in June 1982 and did not resume normal operations until October 1983.

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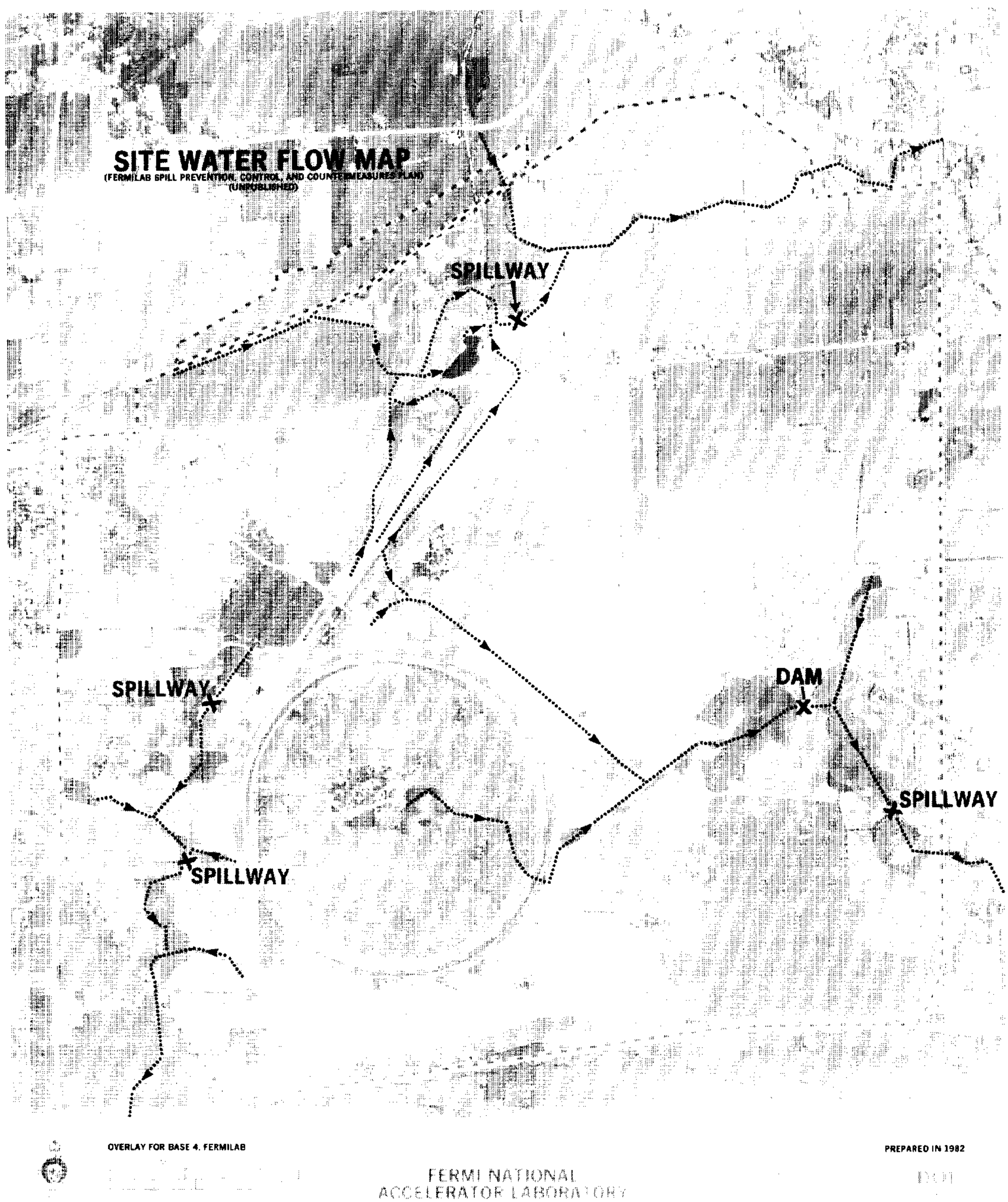
FIGURE 8



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Silt and vegetation samples were taken near discharge points for radioactive effluents. The results for silt samples are given in Table 2. The vegetation results are given in Section 3.3.3.

TABLE 2

Silt Sampling Results for CY-1983

Location	Radionuclides	Concentration (pCi/g)
DO Sump Discharge Area at Main Ring Pond	^{22}Na	0.6 ± 0.06
	^{54}Mn	0.2 ± 0.03
	^{60}Co	0.1 ± 0.04
MF5 Sump Discharge Area	^{22}Na	0.4 ± 0.06
	^{54}Mn	1.3 ± 0.1
	^{57}Co	0.3 ± 0.04
	^{60}Co	0.4 ± 0.09
N2 Sump Dicharge Area	^{22}Na	0.2 ± 0.02
	^{54}Mn	0.2 ± 0.02
	^{60}Co	0.1 ± 0.01
T3 Sump Area at Main Ring Pond (AO Ditch)	^{22}Na	1.4 ± 0.1
	^{54}Mn	0.4 ± 0.04
	^{60}Co	0.1 ± 0.02

3.3.2.3 Other Radionuclides

Radioactive surface soil was found adjacent to the evaporator at the Boneyard (Fig. 4) in CY-1982. In this case the principal radionuclide was ^{57}Co and the concentration was approximately 2 nCi/g. The contamination occurred during the filling of the evaporator. Some of this activity was removed for disposal in CY-1983. More soil samples were taken and some remaining activity still needs to be removed.

Tests were also made for radium and thorium in our deep well (4 in Fig. 6) to look for any long-term changes in percolation rates to deep-lying aquifers. The results were consistent with no changes, as has been the case in the past.

3.3.3 Vegetation Sampling

An annual vegetation sampling program was initiated in CY-1978. In CY-1983 a vegetation sample was taken near the ^{11}C exhaust in the Neutrino Area (N1 in Fig. 7). In addition, a vegetation sample was taken next to the evaporator in the Boneyard where ^{3}H from closed loop systems is disposed of by release to the atmosphere. See Table 3.

TABLE 3

Vegetation Sampling Results

Location	Radionuclides	Concentration (pCi/g)
Boneyard	^{3}H	204 ± 3
N1 Labyrinth Stack	^{3}H	233 ± 3
	^{7}Be	15 ± 3
	^{22}Na	0.4 ± 0.1
	^{54}Mn	3 ± 0.2
	^{57}Co	0.2 ± 0.05
	^{60}Co	0.5 ± 0.2

1983

The peak concentrations for vegetation sampling are based on the weight of the unprocessed sample. From previous results[18] the radionuclide ^{7}Be is expected to be present as surface contamination while ^{22}Na and ^{54}Mn are most likely incorporated into the plants. The results from the analyses of the vegetation samples indicated small concentrations of radionuclides similar to those seen in the past.[19] The presence of ^{3}H is to be expected at the N1 Labyrinth Stack since ^{3}H has a long half-life (12.3 years) and was produced along with short half-life ^{11}C during past operations.

3.3.4 Soil Activation

Since the percolation rates for water in Fermilab soils are calculated to be very low - less than 1 m (3 ft) per year[20] - analyses of well waters do not provide the early warning desired for detection of accelerator-produced radioactivity in the ground water. To provide such a warning soil samples were taken from the vicinity of targets and other locations where proton interactions result in some radioactivation of the soil. Many radionuclides were detected but since the major long-lived ones leachable from Fermilab soils were ^{3}H and ^{22}Na, quantitative measurements were made only on those.[16]

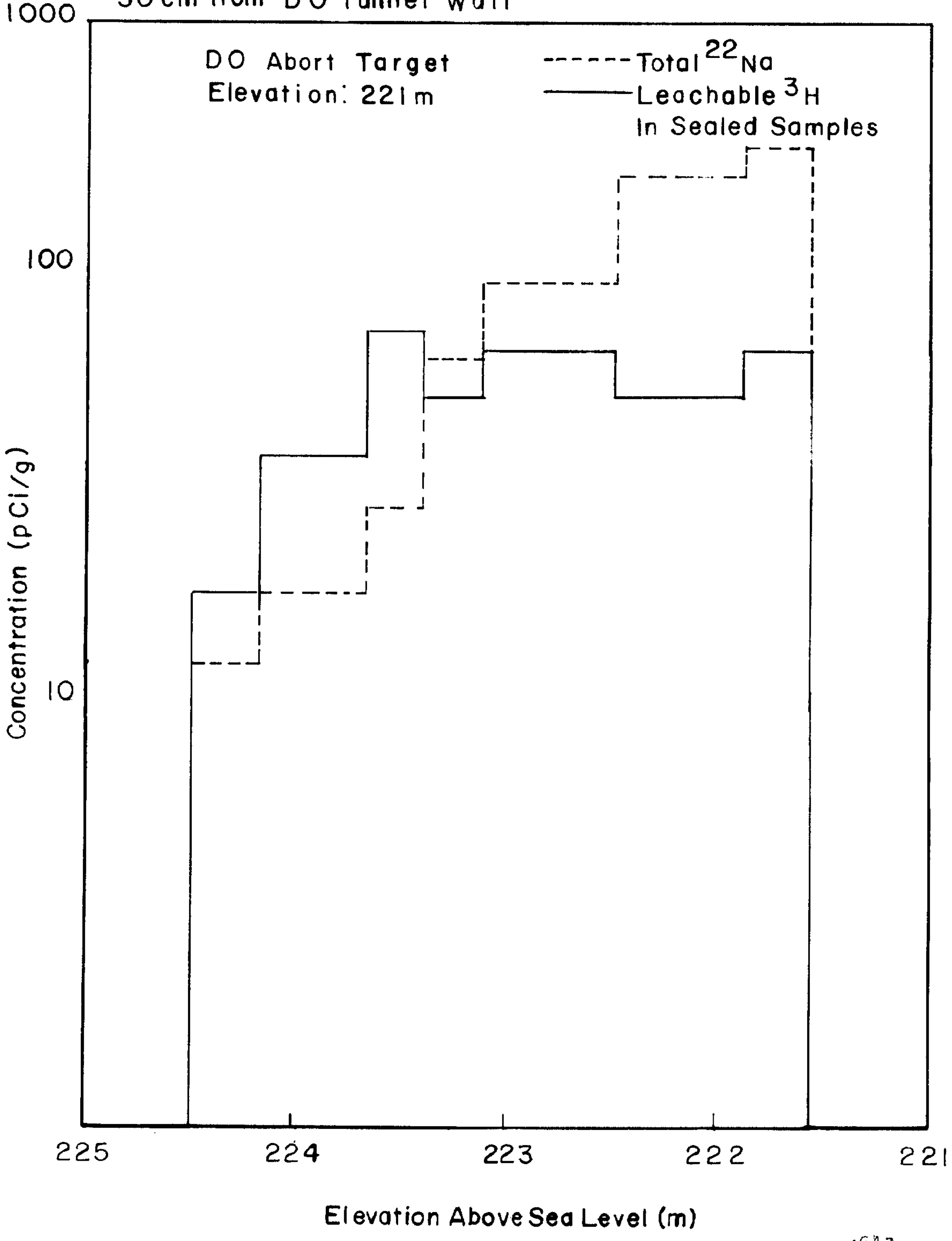
In CY-1983 a hole was drilled near the D0 Abort Target (D0 in Fig. 7) to determine soil activation levels and measure the water percolation rate, if any leaching of radioactivity had occurred. The leaching was determined by comparison with sealed samples from coring done ten years earlier. The

1983

new hole was made three feet farther from the tunnel wall to allow a deeper hole without disturbing the underdrain system which lies adjacent to the tunnel wall.

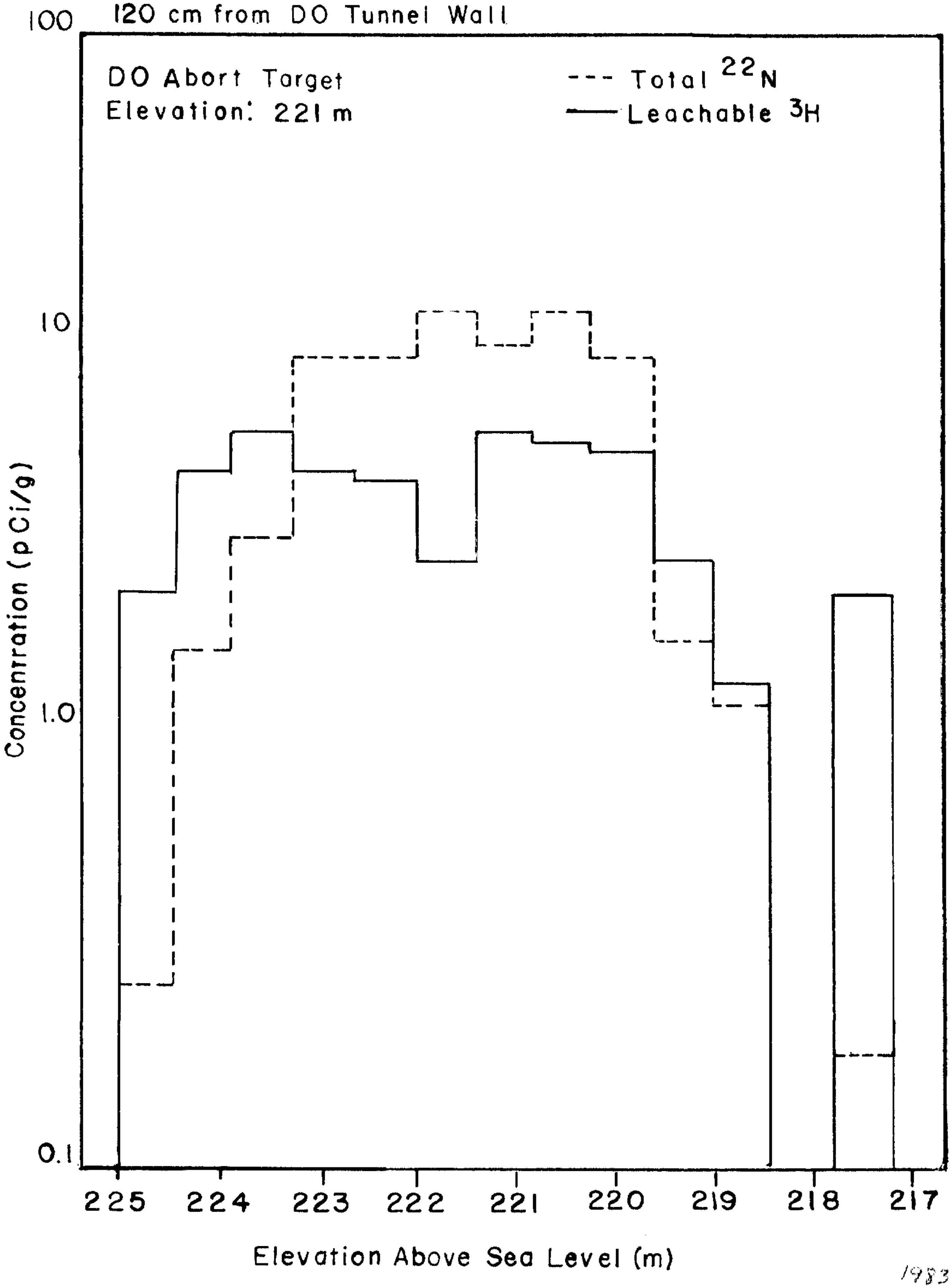
The ^{22}Na and ^{3}H concentrations in the soil samples recovered from the two holes are shown in Figures 9 and 10. There is some evidence for higher concentrations of ^{3}H relative to ^{22}Na at higher elevations as well as lower, as was seen at Enclosure 100.[18] Also, there was a pocket of water at Elevation 218 m above sea level, which is 2 meters below the underdrains. The ^{3}H level was 3 x 10^{-6} μCi/mℓ (15% of the Concentration Guide for community water systems) in water taken from that elevation. See Section 5.

Figure 9. Soil Activation Measurements 30 cm from DO Tunnel Wall



1983

Figure 10. Soil Activation Measurements 120 cm from DO Tunnel Wall



1983

3.4 Nonradioactive Pollutants

3.4.1 Water Utilization

3.4.1.1 Domestic Water Supplies

The domestic water supply at Fermilab is essentially provided by two wells pumping from an aquifer approximately 70 m (220 ft) deep. One (1 in Fig. 6) is located in the Central Laboratory area and the other (62 in Fig. 6) supplies the separate Village system. A third well (3 in Fig. 6) pumps from the same aquifer and supplies water to the Main Site System when demand exceeds the capacity of the Central Laboratory well (1 in Fig. 6).

These wells have chlorination systems and our water laboratory tests for pH and fecal coliform monthly. The chlorine level in the chlorinated drinking water supplies is tested each work day. Test results conformed to Illinois standards during 1983, except for 18 tests of drinking water from the Main Site System which contained no chlorine. Most of these occurred in September and October while the weighing scale for determining the amount of chlorine added was inoperative. No coliform was found. Our average use from these wells was approximately 300,000 ℓ/day (79,000 gal/day), a decrease from 1982.[19]

3.4.1.2 Industrial Water Ponding Systems

There are several water systems used for cooling magnets and for fire protection:

1983

The Industrial Cooling Water (ICW) System consists of Casey´s Pond (Fig. 4) at the end of the Neutrino Beam Line and underground mains to fire hydrants and sprinkler systems throughout the Main Site and Wilson Hall. Casey´s Pond is supplied by surface drainage and can also be supplied by pumping from the Fox River. The pond, holding 68,000,000 ℓ (18,000,000 gal), is accessible to the public.

The Swan Lake/Booster Pond System (Fig. 4) is used for cooling purposes at the Central Utilities Building (C.U.B.). Water is pumped from the Booster Pond into a ditch in which it runs by way of a small West Pond into Swan Lake. The water is then returned to the Booster Pond by a return ditch. Water is also pumped from Swan Lake to NS1 Service Building (N1 in Fig. 7) for cooling purposes, from which it returns by a surface ditch. This system can be supplied water from the ICW System and it overflows into Indian Creek (Figs. 4 and 8).

The Main Ring Ponding System consists of a series of interconnecting canals completely encircling the interior of the Main Ring with a large reservoir pond inside the Main Ring Ponding System (Fig. 4). This water is used in heat exchangers at the Service Buildings for cooling the Main Ring magnets. The system is generally supplied by surface drainage, although make-up water can be pumped from Casey´s Pond. The system overflows into Lake Law (Figs. 4 and 8). The public is excluded from the area inside the Main Ring, and hence the Main Ring Ponding System, when the accelerator is in operation. The water in these systems normally meets the quality requirements of water in general use in Illinois (Section 5). There was an

1983

exception to this during spraying of the Main Ring Ponding System with copper sulfate in CY-1981. No copper sulfate has been applied to this system or any others at the Laboratory since then.

3.4.1.3 Other Lakes and Ponds

Surface drainage from the eastern portion of the site flows into Lake Law, DUSAF Pond and the AE Sea (Figs. 4 and 8). The chlorinated effluent from the Village sewage treatment plant oxidation pond (just north of DUSAF Pond) also flows into DUSAF Pond. These lakes and ponds are accessible to the public, and they are the head waters of Ferry Creek.

3.4.1.4 Tests for Pollutants

Semi-annual tests are made of water samples taken where the three creeks leave the site (R1, R2A, and R3 in Fig. 7), as well as from Casey's Pond and the Fox River. Results for 1983 are found in Table 4. Tests for fecal coliform bacteria are made monthly in our water laboratory.

1983

TABLE 4

Site Wide Water Quality Report for CY-1983

	pH		DO mg/ℓ		BOD5 mg/ℓ		Susp. Solids mg/ℓ		Fecal Coliform mg/ℓ	
	April	Sept.	April	Sept.	April	Sept.	April	Sept.	April	Sept.
Ferry Creek	7.8	No Flow	9.6	No Flow	3.8	No Flow	223	No Flow	0	8
Kress Creek	7.5	7.9	9.4	8.6	3.2	1.8	72	10	0	0
Indian Creek	7.5	7.7	9.4	8.6	2.4	1.8	57	56	0	0
Casey's Pond	8.1	8.1	10.8	8.5	3.1	2.5	88	15	0	0
Fox River	7.9	8.1	10.9	8.4	3.4	3.6	111	53	2	0
General Standards[21]	6.9 - 9.0		Not less than 5.0 at any time		*		*		Mean of 200	

*There are standards for effluent from treatment works or waste water sources, but no general standards.

1983

3.4.2 Sewage Treatment

An authorization permit to discharge under the National Pollutant Discharge Elimination System (NPDES) was obtained for the Village Oxidation Pond (just north of DUSAF Pond in Fig. 4) in 1979.[21] An application to renew this permit has been submitted to the Illinois Environmental Protection Agency. Monthly testing results for 1983 are in Table 5.

The Main Site sewer system was connected to the City of Batavia system June 26, 1979 and has been delivering sewage to the Batavia sewage treatment plant since that time.

The NPDES permit for the Village sewer system granted in 1979 has limits for 30 days average BOD5 and suspended solids of 10 mg/ℓ and 12 mg/ℓ, respectively. The Village system exceeded the limit for suspended solids five times in CY-1983, in spite of treatments with Aquazine to control algae. The limit for BOD5 was exceeded twice. See Table 5.

1983

TABLE 5

Village Sewage Treatment Plant

Monthly Averages Report for CY-1983

Parameter	Permit Limit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
pH	6-9	8.6	7.8	7.6	8.8	8.1	7.8	7.2	7.5	7.4	7.3	7.6	7.2
BOD5 mg/ℓ	10	6.0	1.8	0.3	9.3	10.2*	27.2*	6.8	6.1	3.1	1.0	3.7	3.0
Suspended Solids mg/ℓ	12	10.5	8.0	6.0	28.5*	14.5*	22.5*	28.0*	13.0*	7.0	7.0	7.5	4.5
Fecal Col. #/100 mℓ	400	25	4	0	0	72	**	0	0	0	0	0	0

*Violation Report filed
**Not sampled

1983

3.4.3 Chemical Treatment of Water Systems

Some chemical treatment of our various water systems is required each year to control the growth of algae and aquatic weeds. Only EPA registered agents are administered by trained personnel following the manufacturer's directions.

3.4.3.1 Dalapon

Dalapon was used to treat drainage ditches for control of cattail (*Typha sp.*) growth. Applications were made to ditches in the external experimental areas and along the Main Ring Road inside the main accelerator. A total 329 kg (725 lb) was applied to an estimated 34 km (21 mi) of drainage ditches.

3.4.3.2 Diquat

Diquat has been used to treat the Main Ring cooling ponds for control of duckweed (*Lemna minor sp.*) in the past. None was applied in CY-1983.

3.4.3.3 Chlorine

In addition to the routine chlorination of the domestic water systems, the swimming pool and the Village Oxidation Pond, a chlorination system for the Swan Lake cooling pond system has proved successful in helping to eliminate the need for chromate treatment of the cooling towers. Chlorine

1983

is added to the cooling water for a period of 30 minutes four times a day at a rate which results in a chlorine concentration of 0.5 ppm as the cooling water leaves the equipment.

3.4.3.4 Aquazine

As previously mentioned, it was necessary to treat the Village Oxidation Pond to control algae growth and reduce suspended solids. The pond was treated a total of six times in CY-1983, following the manufacturer´s application instructions. The total quantity of Aquazine used was 450 kg (1000 lbs).

Aquazine was also used to treat a part of the Main Ring Ponding System and all of the Swan Lake/Booster Pond System in CY-1983. Approximately 180 kg (400 lbs) of Aquazine was applied to the eastern third of the Main Ring Ponding System and 39 kg (85 lbs) was applied to the Swan Lake/Booster Pond System.

3.4.4 Heavy Metals and Other Toxic Materials

The continued success of the Swan Lake cooling pond system again made it possible to eliminate the use of chromates in 1983. Although it was necessary to use the cooling towers during the warm summer months, it was not necessary to treat the towers with chromate compounds. The chlorinated Swan Lake cooling pond water was passed through the cooling system and a biodispersant, Nalco 7348, was added which lifted deposits from the metal surfaces so they could be oxidized by the chlorine. The rate of application was 3.6 kg (8 lbs) per day with a peak concentration of 20 mg/ℓ. Nalco 7348 is a polyglycol manufactured by Nalco Chemical Company, 2901 Butterfield Road, Oak Brook, Illinois 60521. Another Nalco product, Nalco 7387, was applied continuously at less than 1 mg/ℓ. The rate of application was the same per day as for Nalco 7348. Nalco 7387 is an organophosphorus compound which prevents scale formation. It does not have the toxic properties of organic phosphorus esters found in some restricted-use pesticides.[22]

For about 20 days in CY-1983 the pond cooling water system could not be used because of construction activities. While the Central Utilities Building cooling towers were operated as a closed loop system, a stronger Nalco product, Nalco 7317, was introduced to prevent scale formation. The total amount used was 534 kg (1175 lbs) at a peak concentration of 50 mg/ℓ. This product is similar to Nalco 7387. There was some build up of solids in the cooling water during this period, requiring some discharge (blowdown) to the CUB Tile Field (Fig. 7).

1983

Water samples were collected from Casey's Pond and Lake Law (Fig. 4) and analyzed for chloride from run-off of salt applied to Fermilab roads. These two reservoirs collect and store water as shown in the Site Water Flow Map (Fig. 8). When water is below the spillway, the flow goes into Casey's Pond from both entrances rather than leaving it. The water sample analyses were performed by Gabriel Laboratories, Ltd., 1814 North Marshfield, Chicago, Illinois 60622. The results were 86 mg/ℓ for Casey's Pond and 79 mg/ℓ for Lake Law. These concentrations are well below the applicable limit of 500 mg/ℓ for waters in general use. See Section 5.

In addition to the above samples a water sample from the Main Ring Ponding System (Fig. 4) was analyzed for chloride. This ponding system is close to the CUB Tile Field and could possibly have received some run-off water from the tile field.[19] The concentration found in that sample was 43 mg/ℓ.

The Photo Lab sump in Wilson Hall (Fig. 1) was sampled for silver, cyanide and suspended solids. The silver concentration was 0.06 mg/ℓ, which is less than the standard of 0.1 mg/ℓ for discharge into waters in general use. See Section 5. Cyanide and suspended solids concentrations were greater than the standard: 0.06 mg/ℓ for cyanide compared to the Standard of 0.025 mg/ℓ and 107 mg/ℓ for suspended solids compared to 15 mg/ℓ. This sump discharges into Swan Lake (Fig. 4).

1983

In CY-1983 a biennial program of monitoring wells for non-radioactive pollutants was begun. Eleven drinking water wells* (Fig. 6) and two wells (20 and 45 in Fig. 6) near the CUB Tile Field (Fig. 4) were sampled directly. Also, samples were taken from the distribution systems of three of the 13. The water was analyzed for 12 metals including arsenic, chronium, iron, lead, mercury, and zinc. Total dissolved solids, chloride, fluoride, sulfate, and nitrate plus nitrite were also measured as well as pH and cyanide. The Main Site well water supply total dissolved solids level was 560 mg/ℓ, slightly above the recommended maximum of 500 mg/ℓ. (Section 5). Well #29 was above the recommended maximum for dissolved solids and sulfate. That well is used by a single family. Wells 17A and 50 were also above the recommended maximum for dissolved solids. Well 17A supplies a low occupancy accelerator support building (RF Building) and bottled water is used for drinking water instead of Well 50. The analyses were performed by Environmental Research Group, Inc., Bridgeview, Illinois 60455.

There were no ethylene glycol spills in CY-1983 and no sampling of silt and run-off water was done in CY-1983 for fields, ditches, and ponds treated with pesticides.

*Wells 56 and 58 south of 55 in Fig. 6 were substituted for Wells 12 and 43 which are not being used for drinking water at the present time.

1983

A test for dioxin was made of the lithate 2, 4 D solution as received from the manufacturer. This test was performed by Gabriel Laboratories, Ltd., 1814 North Marshfield, Chicago, Illinois 60622. No dioxin was found at a detection limit of 2 μg/ℓ (2 parts per billion).

Tests were made for PCBs in fish taken from the Booster Pond (Fig. 4) in CY-1983. A bottom feeder: a bullhead catfish (Ictalurus sp.), and a surface feeder: a bluegill (Lepomis machrochirus Rafinesque), were collected. The reported concentrations were 0.07 ppm for the catfish and 0.05 ppm for the bluegill. These concentrations are well below the limit of 2 ppm for human consumption. See Section 5. The analyses were performed by Gabriel Laboratories, Ltd.

3.5 Environmental Impact

3.5.1 Assessments of Potential Radiation Dose to the Public

Fermi National Accelerator Laboratory is located in the densely populated Chicago Area. There are about eight million people living within 80 km (50 mi) of the site.[23] There are 326,645 people within 16 km (10 mi) of the center of the main accelerator based on the 1980 census results compared to 265,677 counted in the 1970 census. The detailed distribution of population as a function of distance and direction from Fermilab is given in Table 6.[23] The population distribution close to Fermilab is shown in Figure 11.

The dose rate at the site boundary from Fermilab operations was primarily from muons. Earlier measurements of muons showed they went in one direction (toward the northeast). The maximum annual dose rate at the site boundary and the annual dose to the off-site individual receiving the maximum dose from Fermilab operations are essentially the same since the change in distance is small to the site boundary to off-site housing compared to the change in dose rate with distance. The total dose to the individual is 0.04 mrem for CY-1983. The point where that exposure occurred is along the path muons traveled which originated in the Proton Area. This is approximately 0.03 percent of the background radiation dose.[24]

1983

TABLE 6

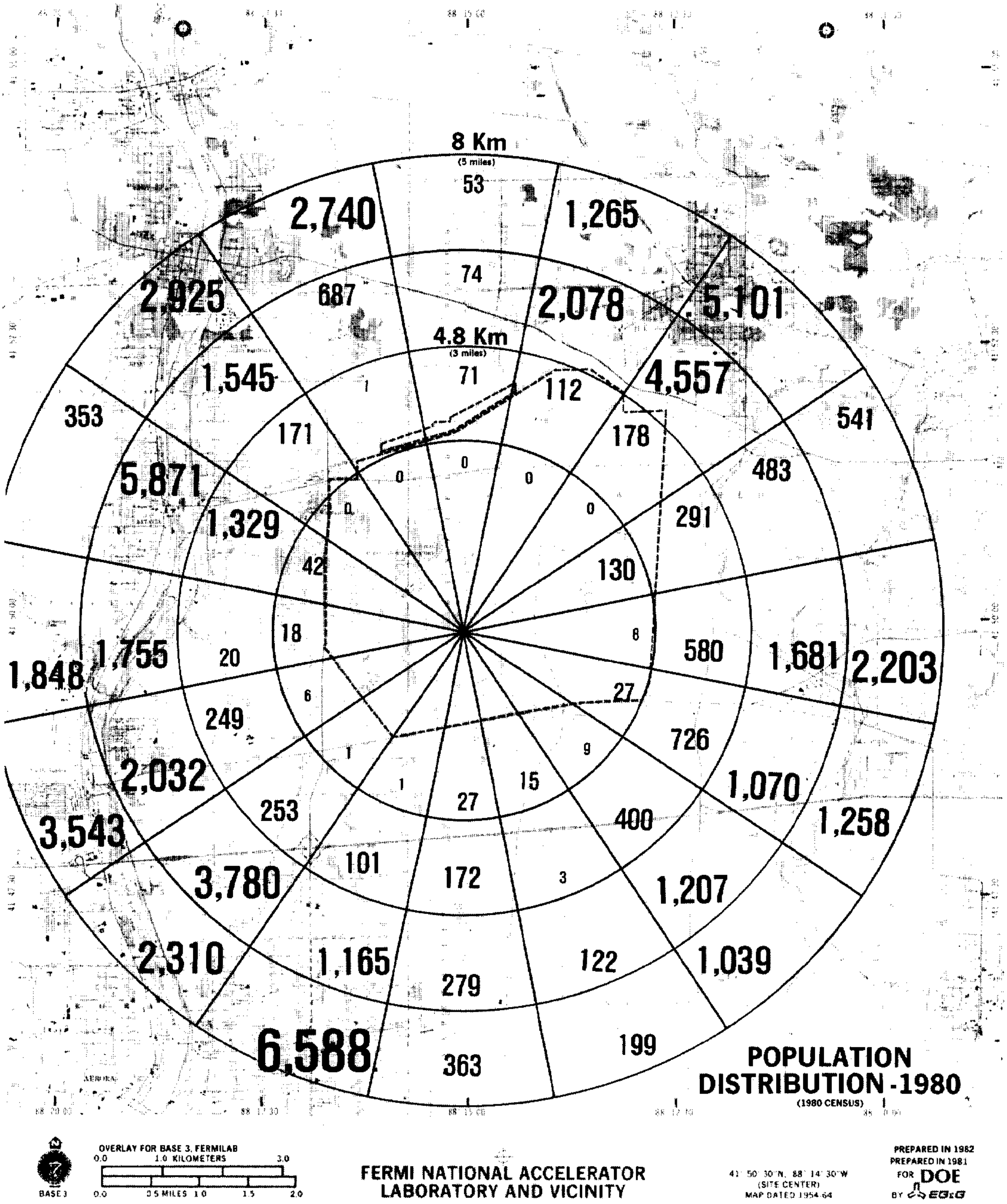
Incremental Population Data in Vicinity of Fermilab, 1980

LATITUDE = 41.832 LONGITUDE = 88.251

DISTANCE, KILOMETERS FROM CENTER OF MAIN RING	0-8	8-16	16-32	32-48	48-64	64-80	80-97	97-113	113-128
DISTANCE, MILES	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80
DIRECTION									
N	198	1110	77247	75658	63188	37183	30696	28459	149892
NNE	3455	5821	68274	76075	120930	145415	100858	173092	87495
NE	9836	12718	78701	292724	139718	0	0	0	0
ENE	1445	63784	263526	840460	551913	0	0	0	0
E	4472	18423	218631	1107254	924752	0	0	33317	56442
ESE	3081	15075	92242	268040	597113	379986	196888	78056	17600
SE	2655	25167	37956	34405	106938	38944	24651	11963	10027
SSE	339	3262	44203	148699	7962	21154	70503	10828	13195
S	841	1336	8604	10301	17011	11089	6640	4354	11967
SSW	7055	49656	8635	3492	17420	6373	25217	24588	10469
SW	6344	35851	13598	15566	5317	30917	36362	13671	13226
WSW	5030	2205	5578	6322	4509	10930	8474	11704	12175
W	3641	971	2941	5339	5111	13693	8445	28768	49103
WNW	7595	851	3018	42762	6723	21231	40449	13891	37012
NW	4641	9607	3297	7974	7358	65288	157549	71682	28229
NNW	3428	15152	22722	10674	29830	17952	29399	24276	58430
TOTAL	65656	260989	949171	2945745	2605793	800155	736131	528649	555262
CUMULATIVE TOTAL	65656	326645	1275816	4221561	6827354	7627509	8363640	8892289	9447551

1983

FIGURE 11



1983

The radiation exposure to the general population from operation of Fermilab in CY-1983 was less than 0.1 person-rem. This exposure was from muons. This is to be compared with a total of approximately one million person-rem to the population within 80 km (50 mi) from natural background radioactivity.[23,24] Radiation from diagnostic x-rays, medical treatments, and other artificial sources accounted for about 500,000 person-rem in CY-1983.[24]

The exposure from muons was determined by starting with the dose to the maximum individual near the site boundary and calculating dose versus distance from the point on site where the penetrating radiation (Section 3.1) originated to 80 km (50 mi) from the site using the inverse square of the distance and summing over the appropriate numbers of individuals. The dose was received by individuals living only in a portion of the northeast sector. See Table 7.

TABLE 7

Summary of Population Exposures for CY-1983 Within an 80 km (50 mi) Radius of Fermilab

Source	Contributions to Population Exposures (person-rem)
Penetrating Radiation from Proton and Meson Areas	< 0.1
Penetrating Radiation from Neutrino Area	0.0
Airborne Radioactivity from All Areas	0.0
TOTAL	< 0.1

1983

Several of the closed loop cooling systems were drained during the extended shutdown. These were at levels where potential off-site releases, from these loops, would be detectable but not hazardous. The tritiated water was evaporated. See Section 3.2. No releases occurred from these closed loop systems in CY-1983. Some releases of radioactive water occurred from sumps collecting water from under areas where protons interacted. About one-third of this volume of water left the site while Casey´s Pond (Fig. 4), the reservoir receiving water from discharges in the three external areas to which protons are delivered, was full. The mean concentration of tritium during the period of release was less than one percent of the Concentration Guide for uncontrolled areas. Also, drinking water in the area is taken from wells rather than from the creek receiving the discharge. Hence, the dose from the release is negligible.

The D0 abort system was replaced by a new abort system at C0 in CY-1983, featuring a well-shielded dump (at C1 in Fig. 7). Therefore, no additional soil activation is expected near D0 in the future. The soil was sampled near D0 in CY-1983 (Section 3.3.4). Based on those sampling results, no environmental impact is expected from the D0 abort system. The soil activation associated with the new system at C0 should be much lower than at D0.

1983

3.5.2 Assessment of Nonradioactive Pollutant Releases

Although it was necessary to chemical treat some waters to control the growth of algae and weeds during CY-1983, efforts were made to keep these treatments as low as possible in order to protect wildlife and fish, i.e., well within guidelines established by the State of Illinois.

The magnet debonding oven was not used to debond radioactive magnets in CY-1983. There were no other activities during CY-1983 which created problems with respect to nonradioactive airborne effluents. Heating is accomplished by use of natural gas, liquefied propane gas, or electricity. The bulk of the heating is supplied by natural gas fired boilers located in the Central Utilities Building. The effluents from these boilers are analyzed annually to maintain proper combustion efficiency.

1983

3.5.3 Potential Impact of Other Toxic Substances

3.5.3.1 Pesticides

In addition to the water treatments mentioned in Section 3.4.3, the following EPA registered herbicides, insecticides and rodenticides were applied by trained personnel following the manufacturer's instructions:

Roundup was applied to bases of trees in the Village and at Site 38 (38 in Fig. 6) to control weed growth. Approximately 30 ℓ (8 gal) was applied in CY-1983.

Lithate 2, 4 D was applied to 0.18 km^2 (45 acres) and 2, 4 D Amine was applied to 8.1 km^2 (2000 acres) in 1983 for control of noxious weeds. The areas sprayed were grassy areas. Lithate 2, 4 D was used primarily in the Village. A sample of the concentrated lithate 2, 4 D solution, as received from the manufacturer, was analyzed for dioxin. None was found at a detection limit of 2 ppb. See Section 3.4.4. Since 2, 4 D is biodegradable and no dioxin was found, the impact should be negligible. Lithate 2, 4 D was sampled because it was applied in residential areas. The 2, 4 D Amine was applied in unoccupied areas.

No corn was planted by licensees in CY-1983, some soy beans were grown but no pesticides and fertilizers were applied to this land. One licensee applied 2, 4 D Amine and crop oil to 2.4 km^2 (600 acres) of land not plowed in CY-1983. Application of these was supervised by Fermilab.

1983

Spike 80-W, EPA Registration No. 1471-97, was applied to control weeds around electrical substations, parking lots, hardstand (crushed limestone) areas, air conditioner pads, and service buildings. Approximately 124 kg (264 lb) diluted in 17,600 ℓ (4700 gal) of water was applied to 0.13 km^2 (31 acres) during CY-1983.

For mosquito control, an ultra low volume application of CYTHION Premium Grade Malathion was performed at 12 different times. Approximately 7.6 ℓ (2 gal) of CYTHION were used in each application and the following areas were covered: Village and Sauk Circle just south of the Village (Fig. 1), Sites 29, 38, and 43 (29, 38, and 43 in Fig. 6), the Meson, Proton and Neutrino experimental areas (Fig. 4), and the Industrial Area (Fig. 1).

For control of tent caterpillars (Malacosoma sp.) a 0.14% solution of malathion in water was applied to the foliage of approximately 900 trees throughout the site.

EATON's AC Formula 50, a rodenticide, was placed in pan-type feeders inside approximately 40 outdoor electrical substations to reduce rodent nesting in this high voltage equipment. Approximately 4.5 kg (10 lbs) was used in CY-1983.

The services of a contract exterminator, licensed by the State of Illinois and using EPA registered pesticides, was retained during 1983 for the control of miscellaneous pests found in kitchens, laboratories and living areas throughout the site.

1983

3.5.3.2 Polychlorinated Biphenyls

An inventory of polychlorinated biphenyls (PCBs) is maintained, and a Status Report as of January 1, 1983 listed 65 PCB transformers and 2,138 large capacitors in use or storage for future use. These PCB items have been labeled as required. These totals differ from last year's totals primarily because a number of PCB transformers were drained and processed to remove PCBs in CY-1982.[25] Also, many capacitors were disposed of by incineration in an EPA - approved incinerator.[26]

During CY-1982 a major effort was made to reduce PCB concentrations in transformers and dispose of PCB wastes.[25] Fourteen PCB transformers were processed using the Zero/P.C./Forty system, a Freon® TF hot solvent PCB removal system. Six of these transformers were askarel-filled. Five were then filled with silicone fluid, a substance with better fire protection properties than oil.

A carbon filtering system was tested on two of the silicone-filled transformers. The PCB concentration was reduced from approximately 700 to 70 ppm in the first case when the transformer failed. In the second case the concentration was reduced from approximately 700 to less than 10 ppm. Unfortunately, that transformer soon failed, too. Thus, the problem was related to the filtering process. Moisture absorbed by the carbon in transport from the manufacturer entered the transformer and caused a short circuit in the primary winding.

1983

In addition to removal of PCBs from transformers, 210 PCB capacitors and 37,100 ℓ (9800 gal) of PCB oil in storage was shipped off-site for disposal in an EPA-approved incinerator. Also, one askarel-filled failed transformer and 38 drums of solid waste contaminated with PCBs were shipped for off-site disposal. Consequently, the probability of environmental impact from PCB spills has been greatly reduced. PCB concentrations in two fish taken from the Booster Pond (Fig. 4) were measured as a follow up to an earlier report of 45 ppm in a Booster pond fish.[13] The concentrations found were 0.07 and 0.05 ppm. This is further evidence that the earlier report was incorrect.

3.5.3.3 Hazardous Wastes

Significant progress was made during 1983 with respect to identification, collection and disposal of hazardous waste in an environmentally acceptable manner. Responsibility for this program was assigned to the Safety Section in CY-1979 and a hazardous waste handling and storage facility was developed at Site 55 (near 55 in Fig. 6). This facility is roofed and fenced, has hardstand and two concrete containment areas. An additional facility with concrete containment area for PCBs was developed at Site 3 where the Environmental Monitoring Station is located (Fig. 4). This facility is for inside storage of hazardous materials which are for future use. In CY-1982 a PCB storage building was constructed at Site 55 which is much farther from the site boundary that Site 3. Off-site impact from an airborne release of PCBs was greatly reduced when most of the PCB items were removed from Site 3.

1983

Over the years it has been the practice to deposit excess materials such as lumber, concrete, building materials and earth on the Meson Area shielding hill. To assure that none of these materials are hazardous to the environment and none will contribute to the contamination of surface or ground waters, a program to control such deposition was developed during 1979. Rules have been promulgated and responsibility for access and control has been assigned to the Roads and Grounds group. The Safety Section monitors this program. In 1982 burial of wood, paper and other wood products on the hill was halted.

3.5.3.4 Heavy Metals

No copper sulfate was used to treat the ponding systems in CY-1983. There was no evidence of any further impact from the treatment in CY-1981.[13] Copper solution from the etching of printed circuit boards was disposed of as hazardous waste. Chromate treatment of the cooling towers has been replaced by biodegradable treatments. Only trace amounts of copper were released in the CUB Tile Field. Thus, the environmental impact from heavy metals released in CY-1983 should be negligible.

3.5.3.5 Chlorides

The potential environmental impact of release of chlorides into the CUB clay tile field (Section 3.4.5) has been evaluated. Assuming the salt released in one year all ends up in the nearest drinking water well (W1 in Fig. 4) and is diluted in the water normally pumped from that well for one

1983

year, the concentration would be less than 25% of the applicable limit of 250 mg/ℓ.[28] Thus, the environmental impact should be minimal.

A similar analysis was conducted for the impact from salt applied to Fermilab roads in the winter. A similar result was obtained.

Casey's Pond and Lake Law (Fig. 4) were sampled for chloride to see if concentrations from salt applied to Fermilab roads might be building up in them. These bodies of water collect and store run-off on the site (Fig. 8). The concentrations observed were about one-third of the drinking water limit. See Section 3.4.4. Thus, any dilution in the aquifer would reduce the environmental impact further.

In early CY-1983 several dozen small (< 453 g or 1 lb) dead fish were found in the Booster Pond (Fig. 4). The cause was traced to over chlorination of the effluent from the cooling towers on the top of the Central Utilities Building. A test was being made of the ability of the system to operate using only the Booster Pond, and the chlorination system had not yet been properly adjusted. The problem was corrected and no more fish died.

3.5.3.6 Cyanide

The Photo Lab sump in Wilson Hall was sampled in CY-1983 primarily to check for silver since the silver was not being reclaimed. The silver concentration was below the limit but cyanide and total suspended solids

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were not. See Section 3.4.4. The amount of film processing done by the Photo Lab is small (3.7 to 4.6 m^2 or 40 to 50 sq ft per day). Thus, the volume of water discharged into Swan Lake and the environmental impact are small. The sump has been cleaned out and the residue in the bottom, which contained higher concentrations, will be disposed of as hazardous waste.

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4. Quality Assurance in CY-1983

Water samples collected in CY-1983 were analyzed by Teledyne Isotopes, Inc., 1500 Frontage Road, Northbrook, Illinois 60062. In addition, such samples were counted at the Fermilab Nuclear Counting Laboratory. Tritium and ^{45}Ca analyses were done only by Teledyne Isotopes, Inc. since Fermilab does not have the necessary liquid scintillation counting system. Each shipment to Teledyne included at least one sample prepared at Fermilab containing known amounts of several of the accelerator-produced radionuclides. Known concentrations of tritium were included in every shipment.

4.1 Analytical Procedures at Teledyne

Teledyne Isotopes, Inc. analyzes water samples using essentially the same procedures as described previously.[13] Liquid scintillation counting is done using a Beckman Instruments Inc. LS-230 refrigerated system. A 1 mℓ aliquot of the sample is placed in 10 or 15 mℓ of the scintillator "InstaGel," manufactured by Packard Instrument Co., Inc., 2200 Warrenville Rd., Downers Grove, IL. 60515.

The samples were subjected to the appropriate one of the following analyses:

Type 1a: Test for ^{3}H (tritium), ^{7}Be, ^{22}Na, ^{45}Ca, ^{54}Mn, and ^{60}Co at surface water sensitivities. See Section 5.

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Type 2a: Test for all of the above at ground water sensitivity plus total radium (the sum of ^{223}Ra, ^{224}Ra, and ^{226}Ra) and total thorium (the sum of ^{228}Th and ^{232}Th).

Type 3a: Chemical separation of ^{45}Ca before its determination; otherwise the same as Type 1a.

Type 4a: ^{3}H only, at surface water sensitivity.

Type 5a: Chemical separation of ^{45}Ca and analysis for ^{45}Ca only, using surface water sensitivity.

Type 6a: The same as Type 1a except at ground water sensitivity.

Type 7a: The same as Type 4a except at ground water sensitivity following distillation.

Type 8a: Test for gross alpha, gross beta, ^{3}H, ^{131}I, and ^{134}Cs at ground water sensitivity. This analysis is performed on Fermilab's one community water system and on other drinking water systems on site which supply water to more than 25 people during the work day.

Type 9a: Test for Sr-90 only, at ground water sensitivity.

Separate analyses of two aliquots from the same sample bottle is indicated by changing the letter "a" to the letter "b" on the Type designation.

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The specifications for the above analyses are given in Table 8.

4.2 Quality Assurance Samples

During CY-1983 the DOE Environmental Measurements Laboratory (EML) quality assurance program was again funded.[27] Fermilab participated in that program. Also, Fermilab sent a set of quality assurance samples to potential vendors as a qualifying test. Teledyne Isotopes, Inc., had the best performance. Results are shown in Tables 9 and 10. The vendor's agreement with the known concentrations was close to the precision specified by Fermilab except when undistilled samples were analyzed for ^{3}H and except for a problem with ^{45}Ca. See Table 8.

TABLE 9

Quality Assurance Results for Fermilab

Sample Date	Radio-nuclide	Percentage of Concentration Guide for Surface Waters* (%)	Prepared Conentration (μCi/mℓ)	Ratio of Fermilab Result to Prepared Concentration
11/82	^{54}Mn	2.2	2.2×10^{-6}	0.96
	^{60}Co	**	2.8×10^{-6}	0.95
5/83	^{54}Mn	1.7	1.7×10^{-6}	0.92

*Individual in Table 8

**Vegetation Sample

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TABLE 8

Specifications For The Analyses Of Accelerator-Produced Radionuclides in Water

		CONCENTRATION GUIDE FOR POPULATION		SPECIFIED SENSITIVITY AND PRECISION*	
Radio-nuclide	Individual (μCi/mℓ)	Suitable Sample (μCi/mℓ)	Community Water System	Surface Water (μCi/mℓ)	Ground Water (μCi/mℓ)
$^{3}\mathrm{H}$	3×10^{-3}	1×10^{-3}	2×10^{-5}	3×10^{-6}	1×10^{-6}
$^{7}\mathrm{Be}$	2×10^{-3}	6.7×10^{-4}	1.3×10^{-5}	5×10^{-7}	5×10^{-7}
$^{22}\mathrm{Na}$	3×10^{-5}	1×10^{-5}	2×10^{-7}	3×10^{-7}	2×10^{-8}
$^{45}\mathrm{Ca}$	9×10^{-6}	3×10^{-6}	6×10^{-8}	3×10^{-7}	6×10^{-9}
$^{54}\mathrm{Mn}$	1×10^{-4}	3.3×10^{-5}	6.7×10^{-7}	1×10^{-7}	7×10^{-8}
$^{60}\mathrm{Co}$	3×10^{-5}	1×10^{-5}	2×10^{-7}	1×10^{-7}	2×10^{-8}

* The precision and sensitivity are stated for the 68% confidence level (one standard deviation). The precision required is the value specified or ± 10 percent, whichever is the lesser precision. The sensitivity is taken to be the minimum concentration which can be detected within the 68 percent confidence level.

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TABLE 10

Quality Assurance Results for Teledyne

Sample Number	Radio-nuclide	Percentage of Concentration Guide for Surface Waters* (%)	Prepared Concentration (μCi/mℓ)	Ratio of Teledyne Result to Prepared Concentration
8310 A	^{3}H	.08	2.4×10^{-6}	1.59**
	^{22}Na	4.67	1.4×10^{-6}	0.97
	^{54}Mn	.06	0.6×10^{-6}	1.14
	^{60}Co	3.4	1.0×10^{-6}	1.08
	^{45}Ca	6.67	0.6×10^{-6}	0.71
	^{7}Be	0.11	2.2×10^{-6}	1.03
8310 B	^{3}H	0.08	2.4×10^{-6}	1.80**
	^{22}Na	4.67	1.4×10^{-6}	1.10
	^{54}Mn	0.06	0.6×10^{-6}	1.12
	^{60}Co	3.4	1.0×10^{-6}	1.23
	^{45}Ca	6.67	0.6×10^{-6}	0.78
	^{7}Be	0.11	2.2×10^{-6}	0.86
8311 A	^{3}H	5.3	159.0×10^{-6}	1.11
	^{22}Na	27.67	8.3×10^{-6}	1.13
	^{54}Mn	28.60	28.6×10^{-6}	0.94
	^{60}Co	70.60	21.2×10^{-6}	1.07
	^{45}Ca	44.44	4.0×10^{-6}	0.88
	^{7}Be	5.82	116.4×10^{-6}	0.88
8312 A	^{3}H	39.7	1192.4×10^{-6}	1.11
	^{22}Na	92.67	27.8×10^{-6}	1.16
	^{54}Mn	71.50	71.5×10^{-6}	0.99
	^{60}Co	680.8	204.2×10^{-6}	1.10
	^{7}Be	14.56	291.1×10^{-6}	0.91
8313 A	^{3}H	0.80	23.9×10^{-6}	1.18**
	^{22}Na	185.00	55.5×10^{-6}	1.15
	^{54}Mn	5.70	5.7×10^{-6}	0.96
	^{60}Co	136.0	40.8×10^{-6}	1.10
	^{45}Ca	15.55	1.4×10^{-6}	1.46
	^{7}Be	0.55	10.9×10^{-6}	1.06
8314 A	^{3}H	31.80	953.9×10^{-6}	1.13
8314 B	^{3}H	31.80	953.9×10^{-6}	1.14
8315 A	^{3}H	13.25	397.5×10^{-6}	1.12

*Individual in Table 8

**Results on undistilled samples

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5. References

The appropriate Radiation Protection Standard for penetrating radiation applied to individuals in uncontrolled areas was taken from the DOE Order 5480.1A, Chapter XI.[2] The annual dose for whole body exposure is 0.5 rem when applied to a suitable sample of the exposed population.

The Concentration Guides used in the analyses of the surface water samples for radioactivity were taken from the DOE Order 5480.1A, Chapter XI, Table II, Column 2 (Water in Uncontrolled Areas) and reduced by a factor of three where appropriate for a suitable sample of exposed population. The smaller of the values given for soluble and insoluble forms has been used in each case. The specifications are given in Table 8. The Concentration Guides for airborne activity were taken from the same source, Table II, Column 1 (Concentrations in Air in Uncontrolled Areas), and divided by a factor of three for determining the total off-site potential dose to the public. For tritium the Concentration Guide from Table II, Column 1, is 2×10^{-7} µCi/mℓ. For ^{11}C the Concentration Guide, 2×10^{-8} µCi/mℓ, was taken from the calculations by Yamaguchi.[28]

The Concentration Guide used in the analyses of ground water samples for tritium were taken from the U. S. Environmental Protection Agency regulations for community drinking water systems.[29] The maximum contamination level permitted for tritium is 2×10^{-5} µCi/mℓ and corresponds to an annual exposure of 4 mrem if one uses the supply as one's sole drinking water source. Note that this is 50 times more stringent than

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the DOE regulation for a suitable sample of the general population, which corresponds to 170 mrem/year. The Concentration Guides for the other radionuclides in Fermilab's analyses of ground water samples have been determined by dividing the surface water concentrations for a suitable population sample by 50 (Table 8). The specified sensitivity and precision of the analyses have been reduced to well below these Concentration Guides.

The Air and Water Pollution Standards for nonradioactive pollutants were taken from Chapters 2 and 3 of the State of Illinois Pollution Control Board Rules and Regulations.[30] The waters on site were considered to be in the "general use" category. The value for total hexavalent chromium for general water quality is 0.05 mg/ℓ. The Standards for total copper at the discharge point and for general water quality are 1.0 and 0.02 mg/ℓ respectively, for silver are 0.1 and 0.005 mg/ℓ respectively, and for cyanide are 0.025 mg/ℓ for both. The maximum contaminant level for chloride in water for general use is 500 mg/ℓ and the level of total dissolved solids is 1000 mg/ℓ. In public drinking water the maximum levels for chloride and total dissolved solids are 250 mg/ℓ and 500 mg/ℓ, respectively.[31] The Air Quality Standards limit the release for SO_2 and oxides of nitrogen to 816 g (1.8 lbs) and 136 g (0.3 lbs) respectively, per 252 million calories (per million btu's) of actual heat input in any one hour.

The appropriate regulations for PCBs and hazardous wastes are found in the U. S. Code of Federal Regulations 40 CFR 761 and 40 CFR 260-265, respectively. The concentration limit is 2 ppm for human consumption of fish.[32]

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